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ECBC-TR-882

AMBIENT BACKGROUND PARTICULATE COMPOSITION OUTDOOR NATURAL BACKGROUND: INTERFERENTS/CLUTTER

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Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorizing documents.

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The objective of this study is to design a Simulated Natural Baekground "Recipe" that comprises materials that cause interferences or "clutter" to the current generation of point and standoff BW detectors. Data were extracted from 2 long-term environmental background studies, whieh provide the rationale/basis (doeumentation) of test ehallenge materials that currently cause False Alarms to be used in realistie (represented) BW chamber challenges. This extensive database provides long-term data (1-2 yr) to adequately represent materials that will be encountered by BW detectors. Data eited were from studies executed by contractors to the United Kingdom (UK), Defense Sciences Technology Laboratory, Porton Down, UK, entitled "Characterization of the UK Biological Aerosol Background 1995-1996 Aerosol Biodiversity Data and the U.S. Department of Defense (DoD) Enhaneed Particulate Matter Surveillance Program (EPMSP) conducted at 15 Middle East U.S. Military locations.

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Chamber	Outdoor natural baekground		JBTDS simulated test recipe

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EXECUTIVE SUMMARY

In an effort to understand better the natural fluctuations of aerosol particulates (also known as interferents or clutter to the biological warfare detection world), you must conduct long term (seasonally) particulate monitoring. Anecdotal short term monitoring attempts (i.e., hours or days) will **not adequately** represent the interferent background composition and concentration that will and can occur at any one site.

To date, **ONLY two extensive long-term background characterization studies have been monitored**. The "Characterization of the (UK) Biological Aerosol Background 1995-1996 *Aerosol Biodiversity Data study"* was conducted under the leadership of The Technical Cooperative Program, executed by the UK Defense Sciences Technology Laboratory, Porton Down, UK. It was an attempt to **characterize and quantify fully the total bio and non-bio background particulates (interferents or clutter)** in the lower atmosphere at four locations along a transect in the UK for 2 years. In addition, seasonal, diurnal, and spatial heuristics were to be sought in understanding their occurrence.

Another relevant long-term (1 year) environmental particulate monitoring effort has been the Department of Defense Enhanced Particulate Matter Surveillance Program. It was one of the first studies to measure and characterize exposures to particulate matter in an effort to access the health effects on military personnel in the Middle East. For approximately 1 year, aerosol and bulk soil samples were collected at 15 military sites to understand fully the mineral dusts, their chemical and physical properties, as well as the interrelationships that exposure to mineral dusts and other aerosols cause to health, as encountered at Forward Operating Bases and Forward Operating Sites.

To design a **Simulated Natural Background "Recipe" (interferents/clutter)**, I have extracted data from the two long-term environmental particulate background studies to provide the rationale/basis (documentation) for this "simulated natural background test recipe" for a realistic interferent challenge to BW sensors. These data provide extensive documented particulates that establish a more realistic (representative) test environment to understand adequately the cause of high false alarms for current BW detector technology (Tables 1-3 in main body of text).

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PREFACE

The work described in this report was authorized under MIPR No. OHDATBD623. This work was started in September 2010 and completed in March 2011.

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AMBIENT BACKGROUND PARTICULATE COMPOSITION
OUTDOOR NATURAL BACKGROUND:
INTERFERENTS/CLUTTER

1. INTRODUCTION/BACKGROUND

The objective of this report is to design/document a Simulated Natural Background "Recipe" (interferents/clutter) to be used by the ATEC community in chamber tests for BW sensors.

It has proven a very difficult task to discriminate an actual BW threat from the natural occurring ambient particulate aerosol, which includes a significant fraction of particles consisting of mixed mineral and biological material. The bio and non-bio interferent particles [clutter] concentration varies widely by location, weather and season, and diurnally. Naturally occurring background particulates are composed of fungal and bacterial spores, fragments and components, plant fragments and debris, and animal fragments and debris, all of which may be associated with inert dust or combustion material. Some or all of which could also be considered to be an interferent to a BW detector and cause these biodector systems to cause False Alarms by these non specific biodetectors. The response of biodetection technologies to the naturally occurring bioaerosol interferents, simulants, and agent are all likely to be dependent on these background constituents. Aerosol components that are interferents for some sensors may not be for others. The composition and concentration of the background environmental aerosol varies significantly by season, location, and time of day, and can be affected by regional and local sources. Regional sources and most local emission sources generally become dispersed and mixed sufficiently that concentrations remain within a factor of two of the mean. The composition generally changes with time constants of at least several hours. On the other hand, rapid changes in the background aerosol occur when local sources are relatively close to the sample point and outdoor climatic conditions are such that little mixing occurs.

Currently, the methodology to the study of airborne microbes is in a transient state, going from almost all the information concerned with relatively well-known **cultural** atmospheric bacteria **(colony forming units per milliliter[cfu/ml]), which is 0.1-10% of actual total** present, to the relatively little known but more inclusive **total** atmospheric bacterial, viral, and fungal populations. The latter is the recent result of increased use of **molecular biological techniques of identification and quantification**.

Most bacteria probably are liberated from natural sources (e.g., vegetation and soil surfaces) by atmospheric turbulence and marine and freshwater spray sources. Bacteria can be transported great distances. Viable (i.e., **live or 0.1–10% of the total**) and nonviable (i.e., dead) microorganisms enter the atmosphere as either single or multiple, naked or rafted (e.g., on plant or soil debris and sea spray) cells from many sources that are planktonic while airborne, and finally are deposited on surfaces by either impaction or gravitational settling. Huge natural long-distance transport sources such as dust storms and many more local natural sources contribute to the so-called background microbial population, all contributing to the ambient atmospheric population. Jaenicke *et al.* (2007) report "by number and volume, the PBAP fraction is ~20% of the total aerosol, and appears rather constant during the year." In addition, they write that "the impression prevails that the biological material, whether produced directly or shed during the seasons, sits on surfaces, ready to be lifted again in resuspension." Some microorganisms have been studied; the majority of other biological particles have not.

Historically, the biological particulate composition of the naturally occurring environmental aerosol background has **not** been and is not studied either extensively or routinely other than for health effects. Allergy caused by pollen (>15 μm) and mold is monitored for health effects by National Allergy

Association, Washington, DC. Most currently existing non-bio particulate data are collected by the Environmental Protection Agency (EPA), Washington, DC on particulate pollutants-(PM10 and PM2.5); (Interagency Monitoring of Protected Visual Environments (IMPROVE) and urban Speciation Trends Network [STN]).

2. UK AEROSOL BIODIVERSITY STUDY-2 YEARS, FOUR LOCATIONS, FOUR SEASONS

Objectives

The objectives of this project were to identify and quantify bioaerosol particulates in the lower atmosphere. In addition, seasonal, diurnal, and spatial heuristics were to be sought to understand their occurrence.

To achieve this, measurement of pollens, bacteria, and fungal spores and dust particulates were undertaken for weekly periods at four representative locations during each season of the year. Sampling was undertaken from 1995 to 1996 at a remote coastal site (the Lizard Peninsula), an urban site, (Birmingham University Campus), and rural areas upwind and downwind of the West Midlands (near Pershore and Lichfield, respectively). See Figure 1 and Appendixes A and B.

Novel and traditional sample collection and detection methods were developed and validated. Innovative genetic techniques capable of determining bacterial identity and concentration were applied. Traditional particulates were measured by PM10 and PM2.5 (Tables 1 and 2). Measurements of meteorological parameters were conducted during the sampling campaigns, along with measurements of chemical and physical parameters of the atmospheric aerosol.

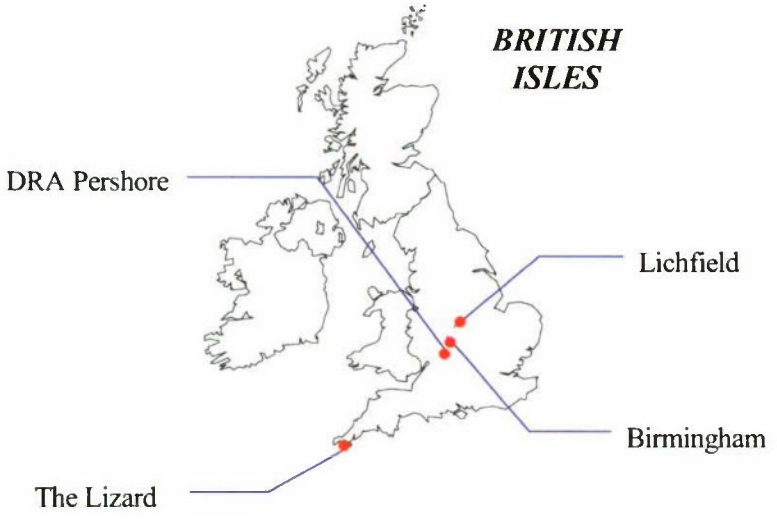

Figure 1. Map of UK Sampling Locations, Lizard, Pershore, Birmingham, Lichfield

Table 1.

Average Data for the Whole Project

Date GMT	Time (from)	PM10 ug/m3	Pollen grains/m3	Fungal spores/m3	Bacteria (cells/m3)	Reflectance 100 - 0	Chloride (ug m^{-3})	Nitrate (ug m^{-3})	Sulphate (ug m^{-3})	5 day Land %	RH (%)	Temp (degs. C)	w. speed (m/s)
MEAN		22	36	3132	10186	77	2.18	3.31	3.49	25	80	9.9	2.9
SD		15	81	4619	8891	18	2.60	3.88	3.19	28	15	6.3	2.3
Min		2	0	0	361	17	-0.34	-0.02	0.00	0	30	-3.9	0.3
Max		102	945	30119	65307	100	20.54	23.92	19.79	100	100	31.3	16.3

Table 2. UK Average Seasonal Data

Date GMT	PM10 ug/m3	Pollen grains/m3	Fungal spores/m3	Bacteria (cells/m3)	Reflectance 100 - 0	Chloride (ug m^{-3})	Nitrate (ug m^{-3})	Sulphate (ug m^{-3})	PAHs (ng/m3)	RH (%)	Temp (degs. C)	w. speed (m/s)
Summer*												
MEAN	21	57	6989	12964	83	1.30	1.93	3.00	1.34	74	16.1	2.5
SD	13	66	5833	7944	13	2.10	1.82	3.02	0.69	17	4.7	1.7
Min	2	0	0	2536	35	-0.08	-0.02	0.00	0.16	30	3.8	0.3
Max	102	415	30119	48412	100	10.35	11.37	17.61	3.49	100	31.3	8.8
Autumn*												
MEAN	23	7	2245	10080	72	3.17	4.11	3.40	4.09	87	7.7	3.0
SD	15	22	2562	9647	20	3.11	4.59	2.77	4.03	9	4.5	2.9
Min	3	0	0	1301	17	0.20	0.04	0.20	0.46	58	-2.6	0.3
Max	92	203	17189	65307	100	20.54	23.92	16.07	18.22	100	15.9	16.3
Winter												
MEAN	27	1	39	5183	68	2.42	4.82	4.86	6.12	81	2.9	3.6
SD	19	2	55	4523	18	1.52	4.92	4.54	4.99	10	3.1	2.5
Min	3	0	0	981	29	0.03	0.07	0.63	0.89	57	-3.9	0.3
Max	89	8	270	23120	99	7.18	21.88	19.79	21.35	96	8.7	11.1
Spring												
MEAN	16	91	595	12511	83	1.87	3.04	3.27	0.56	80	8.8	2.7
SD	10	152	1109	10159	13	2.54	3.29	2.18	0.55	16	3.0	1.6
Min	2	0	0	361	40	-0.34	0.02	0.65	0.03	39	2.1	0.3
Max	61	945	8458	53464	100	13.31	17.26	10.94	2.36	100	16.7	7.9

Appendix A contains a summary of UK total particle number data by location, and Appendix B provides a summary of UK biological data listed by location.

3. DoD SPONSORED *ANALYSIS OF UK AEROSOL BIODIVERSITY DATABASE-2*

Further analysis of UK data is revealed in Figure 2.

- "The intuitive analysis indicated that on average, **the total bacteria (76%) plus the fungal spores (23%) made up almost all of the airborne bioparticles**, while the **pollen** remained **less than 1%.** During winter and spring, the bioparticles were almost exclusively made up of bacteria, while in summer and autumn, 50% were fungal spores. The greatest percentage of pollen was observed at Pershore in the spring at 2%."

- Maximum to minimum "The **maximum number of bioparticles occurred in summer at 67,026 /m^3** and the **minimum in winter at 466 /m^3** with an **annual mean of 13,350/m^3.**"

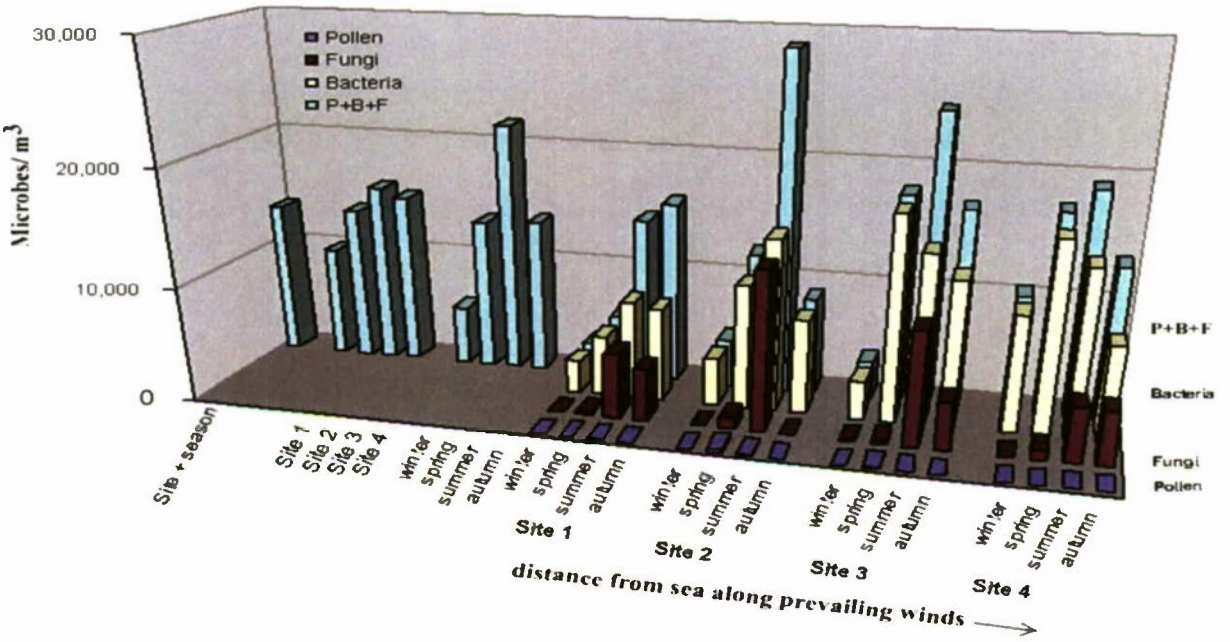

Figure 2. Mean UK Airborne Pollen, Fungi, and Bacteria and/or their Sum @ Four Locations

4. TOTAL VS CULTURABLE MEASUREMENTS OF NATURAL OUTDOOR BACTERIA

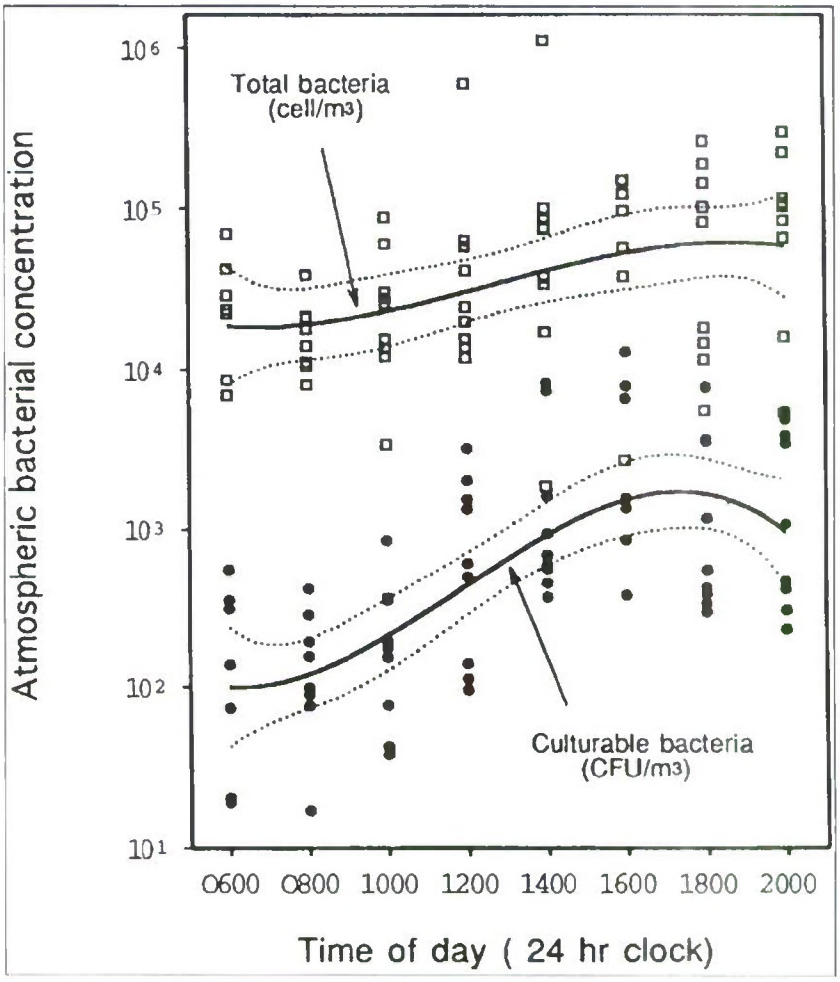

Figure 3. Atmospheric Bacterial Concentration, Total Cells/m^3 and Culturable Bacteria (cfu/ml)

5. CRUSTAL COMPOSITION STUDY IN MIDDLE EAST COUNTRIES

5.1 Background

The **DoD EPMSP** study characterized the three main air pollution sources exposed to the military: geological dust, smoke from burn pits, and, until now, unidentified Pb-zn smelters and battery-processing facilities. See Appendix C and Table 3.

Sampling occurred for approximately 1 year at 15 military sites—including Djibouti, Afghanistan (Bagram, Khowst), Qatar, United Arab Emirates (UAE), Iraq (Balad, Baghdad, Tallil, Tikrit, Taji, Al Asad), and Kuwait (Northern, Central, Coastal, and Southern regions). To understand fully mineral dusts, their chemical and physical properties, as well as mineralogical interrelationships need to be understood along with other aerosols encountered at Forward Operating Bases and Forward Operating Sites (FOB/FOS).

"In general, **the dusts studied from areas in the Middle East are not considered to be out of the ordinary**. **In most cases, comparison of dust samples from the 15 Middle East sites to dust from the United States, Sahara, and China shows similar chemical and mineralogical constituents.** Generally, all dust samples contain mixtures of silicate minerals, carbonates, oxides, sulfates, and salts in various proportions. Differences lie in the relative proportions of these minerals and chemical components in different soils. In comparison to the Sahara, China, United States, and world dusts, the Middle East samples had lower proportions of SiO2 and higher proportions of CaO and MgO. The last two components are contained in carbonates (e.g., calcite and dolomite in the soil) more evident at UAE and Al Asad. Fe2O3 and MnO occur as iron and manganese oxides in greater concentrations in the Sahara, China, and U.S. dusts compared to the 15 Middle East sites. Al_2O_3, a major constituent of clay minerals and other silicates, was similar for most dusts. Sodium generally occurs as salt (NaCl) from evaporated sea water as well as saline desert areas.

In addition to the burn pits, a major potential source of lead (Pb) and associated zinc (Zn), cadmium (Cd), arsenic (As), and antimony (Sb) in the Baghdad-Balad-Taji region are emissions from secondary Pb smelters and related battery manufacturing facilities affecting the population. Since Iraq uses leaded gasoline, vehicle emissions are a contributing source of Pb in the atmosphere."

5.2 Mean Mass Concentration-- Middle East

"In comparison, **average particulate matter and PM2.5 mass and chemical concentration levels from the Middle East deployment sites are**—except for a few instances such as nitrate, sodium, and rubidium—**up to as much as 10 times greater than those from 5 rural (IMPROVE) and 5 urban STN sites in the southwestern United States."**

5.3 Trace Metals--Middle East--EPMSP Data

Annual mean ICP-MS trace metal results of 12 chemical species were compiled per sizecut (TSP, PM10, PM2.5) and sampling site. Pb is the most abundant trace species found in Baghdad aerosol and contributes substantially to measured trace metals at Taji and Balad. Investigators should note that for all sites, the Pb concentrations (micrograms per cubic meter) are nearly identical for the three size fractions (TSP, PM10, and PM2.5). Because PM10 is contained in TSP and PM2.5 in PM10, this implies that most, if not all the Pb occurs in the PM2.5 size fraction. Most combustion products (elemental carbon and particulate organic compounds) also occur in the fine (PM2.5) and ultra-fine fractions, and some Pb

may be a component of combustion products for these locations. Fine Pb and Zn, together with other associated metals, are also generated from condensed fumes emitted by metallurgical processes (e.g., Pb-Zn smelters or backyard electronic circuit board smelting operations). Pb also occurs as an additive in leaded gasoline and is emitted with gasoline vehicle emissions.

A major Pb emitting event, far exceeding the USACHPPM 1-year Air-MEG value of 1.5 $\mu g/m^3$ was recorded at the Baghdad site on 2006-11-30, with a smaller spike on 2007-1-11, and on a few other days. Similar elevated concentration levels also were recorded for Zn, As, and Cd on the same days. This implies that these (and Sb) trace metals were emitted by the same or a collocated source.

5.4 Comparison to Rural and Urban Sites in the United States

To provide a perspective on results from the 15 Middle Eastern sites, we compared these to five rural and five urban PM2.5 sites in the southwestern United States. The 10 U.S. sites were selected because of their proximity to military bases in drier regions of the United States. Average particulate matter and chemical values were calculated from 2002–2006.

The five rural sites are at Dome Land National Wildlife Area, Joshua Tree National Park, Bosque del Apache National Wildlife Refuge (NWR), Salt Creek NWR, and San Andres NWR, which form part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) air quality monitoring network.* The five urban sites are in Las Vegas, NV; Los Angeles, CA; Tucson, AZ; Albuquerque, NM; and El Paso, TX, and form part of USEPA's STN monitoring program.**

* (http://vista.cira.colostate.edu/improve/) (accessed Mar 21, 2011).

** (http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm) (accessed Mar 2, 2011).

Table 3. EPMSP Data
Mean Mass Concentrations for TSP, PM10, and PM2.5 Size Fractions for Middle East and U.S. Desert Environments

Site No.	Site Location	TSP $\mu g/m^3$	Coneentration PM10 $\mu g/m^3$	PM2.5 $\mu g/m^3$	TSP	Ratio PM10	PM2.5
Site 1	Djibouti	94	72	33	1.29	1	0.46
Site 2	Bagram, Afghanistan	174	120	40	1.45	1	0.34
Site 3	Khowst, Afghanistan	185	126	75	1.47	1	0.60
Site 4	Qatar	282	166	67	1.70	1	0.41
Site 5	United Arab Emirates	196	140	52	1.40	1	0.37
Site 6	Balad, Iraq	242	183	56	1.32	1	0.30
Site 7	Baghdad, Iraq	371	250	103	1.48	1	0.41
Site 8	Tallil, Iraq	411	303	65	1.36	1	0.21
Site 9	Tikrit, Iraq	628	300	114	2.09	1	0.38
Site 10	Taji, Iraq	348	213	81	1.63	1	0.38
Site 11	Al Asad, Iraq	142	96	38	1.48	1	0.39
Site 12	Northern Kuwait	416	211	67	1.98	1	0.32
Site 13	Central Kuwait	352	298	117	1.18	1	0.39
Site 14	Coastal Kuwait	264	180	60	1.47	1	0.33
Site 15	Southern Kuwait	290	199	62	1.45	1	0.31
STN	**U.S. SW Urban (City)**		**40**	**12**		1	0.30
IMPROVE	**U.S. SW Rural (Desert)**		**13**	**5**		1	0.36

Mean mass concentrations for TSP, PM10, and PM2.5 size fractions, as well as the TSP: PM10:PM2.5 mass ratios for each of the 15 sites, as measured on Teflon® filters. Included for comparison, the mean STN (southwestern U.S. urban) and IMPROVE (southwestern U.S. rural) concentrations and ratios, from sites in the United States are given.

Appendix C provides the DoD Enhanced Particulate Matter Surveillance Program.

6. ATMOSPHERIC HUMIC-LIKE SUBSTANCES (HULIS)

Background

"**Humic-like Substances (HULIS) are a major contributor to the organic carbon in atmospheric aerosol.**" There is sufficient indication that plant debris and related organic material is a **significant contributor to aerosols of biological origin. Organic carbon content of the environment is of great interest and impact on bioaerosol detectors.**

The organic fraction represents an important part of atmospheric aerosols, from a mass point of view with up to 50% in total mass (Putaud et al., 2004; Pio et al., 2007) and also because it can largely influence the physical and chemical properties of particles.*

Humic substances (HS) are major components of the natural organic matter in soil, water, and geological organic deposits (e.g., lake sediments, peats, brown coals, and shales). They make up much of the characteristic brown color of decaying plant debris and contribute to the brown or black color in surface soils. HS in soils and sediments can be divided into three main fractions: humic acids (HA/HAs), fulvic acids (FA/FAs), and humin.**

HULIS standard--Two products are commonly used in the literature as model compounds for atmospheric HULIS, Suwannee River Fulvic Acid and Humic Acid from Fluka®.

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* http://www.atmos-chem-phys.org/9/5949/2009/acp-9-5949-2009.pdf (accessed Mar 21, 2011).

**http://www.ihss. gatech.edu/ (accessed Mar 21, 2011).

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APPENDIX A
SUMMARY OF UK TOTAL PARTICLE NUMBER BY LOCATION

Source: Harrison, R.H.; Turnbull, A.B.; Beswick, A.J., University of Birmingham: Birmingham, UK, 1996, *BACE STUDY-EMR Contract 20027-00r/CBD, BACE Campaign 1995/96, Aerosol Biodiversity Data, Biodetection CB Systems CBD Porton Down, UK – data -TTCP sponsored.*

Instrumentation Used for Particle Number Measurements

Instrument	Abbreviation	Particle Size	Range (μm)
Aerosol Particle Sizer	APS	Coarse	0.4 - 18
Laser Aerosol Sizer	LASx	Medium	0.1 - 7.3
Electrostatic Aerosol Analyser	EAA	Fine	0.001 - 1

Lizard all seasons

	Σ aps	Σ lasx	Σ eaa
	Particles per cc		
MEAN	11.9	154	10800
SD	11.3	151	41650
Min	84.8	616	423992
Max	0.8	7	858

Pershore all seasons

	Σ aps	Σ lasx	Σ eaa
	Particles per cc		
MEAN	10.8	217	27965
SD	10.4	313	42790
Min	0.9	8	1825
Max	52.9	2046	280355

Birmingham all seasons

	Σ aps	Σ lasx	Σ eaa
	Particles per cc		
MEAN	12.4	497	19966
SD	14.7	524	15269
Min	0.4	4	1904
Max	83.9	2549	83798

Lichfield all seasons

	Σ aps	Σ lasx	Σ eaa
	Particles per cc		
MEAN	6.2	479	35482
SD	5.5	579	38053
Min	0.8	1	2140
Max	24.5	2436	194443

APPENDIX B
SUMMARY OF UK BIOLOGICAL DATA LISTED BY LOCATION

Source: Harrison, R.H.; Turnbull, A.B.; Beswick, A.J., University of Birmingham: Birmingham, UK, 1996, *BACE STUDY-EMR Contract 20027-00r/CBD, BACE Campaign 1995/96, Aerosol Biodiversity Data, Biodetection CB Systems CBD Porton Down, UK – data -TTCP sponsored.*

Lizard all seasons

	Pollen	Spores	Bacteria
	Pollen grains/m3	Fungal spores/m3	Bacteria (cells/m3)
MEAN	17	1923	7624
SD	38	2958	8937
Min	0	0	1264
Max	237	12773	65307

Pershore all seasons

	Pollen	Spores	Bacteria
	Pollen grains/m3	Fungal spores/m3	Bacteria (cells/m3)
MEAN	75	4230	9028
SD	150	6340	6555
Min	0	0	1088
Max	945	28144	32163

Birmingham all seasons

	Pollen	Spores	Bacteria
	Pollen grains/m3	Fungal spores/m3	Bacteria (cells/m3)
MEAN	38	3541	11974
SD	66	5100	9792
Min	0	0	361
Max	524	26253	52542

Lichfield all seasons

	Pollen	Spores	Bacteria
	Pollen grains/m3	Fungal spores/m3	Bacteria (cells/m3)
MEAN	17	2527	12236
SD	30	3178	9187
Min	0	0	1301
Max	139	17189	53464

APPENDIX C
DEPARTMENT OF DEFENSE ENHANCED PARTICULATE MATTER SURVEILLANCE PROGRAM

Mean mass concentrations for TSP, PM10, and PM2.5 size fractions, as well as the TSP:PM10:PM2.5 mass ratios for each of the 15 sites, as measured on Teflon® filters. For comparison, the mean STN (southwestern U.S. urban) and IMPROVE (southwestern U.S. rural) concentrations and ratios, from sites in the United States are given.

Site No.	Site Location	TSP $\mu g/m^3$	Concentration PM10 $\mu g/m^3$	PM2.5 $\mu g/m^3$	TSP	Ratio PM10	PM2.5
Site 1	Djibouti	94	72	33	1.29	1	0.46
Site 2	Bagram, Afghanistan	174	120	40	1.45	1	0.34
Site 3	Khowst, Afghanistan	185	126	75	1.47	1	0.60
Site 4	Qatar	282	166	67	1.70	1	0.41
Site 5	United Arab Emirates	196	140	52	1.40	1	0.37
Site 6	Balad, Iraq	242	183	56	1.32	1	0.30
Site 7	Baghdad, Iraq	371	250	103	1.48	1	0.41
Site 8	Tallil, Iraq	411	303	65	1.36	1	0.21
Site 9	Tikrit, Iraq	628	300	114	2.09	1	0.38
Site 10	Taji, Iraq	348	213	81	1.63	1	0.38
Site 11	Al Asad, Iraq	142	96	38	1.48	1	0.39
Site 12	Northern Kuwait	416	211	67	1.98	1	0.32
Site 13	Central Kuwait	352	298	117	1.18	1	0.39
Site 14	Coastal Kuwait	264	180	60	1.47	1	0.33
Site 15	Southern Kuwait	290	199	62	1.45	1	0.31
STN	**U.S. SW Urban (City)**		**40**	**12**		**1**	**0.30**
IMPROVE	**U.S. SW Rural (Desert)**		**13**	**5**		**1**	**0.36**

PARTICLE SIZE DISTRIBUTIONS BY MASS PERCENTAGE, AS MEASURED BY CCSEM ON TSP NUCLEPORE® FILTERS

Bin Size			0.5-1 µm	1-2.5 µm	2.5-5 µm	5-7.5 µm	7.5-10 µm	10-15µm	>15 µm
Site No.	Site Locality	Site ID	%	%	%	%	%	%	%
1	Djibouti	DJI_LEM	1.2	18.6	36.2	16.1	9.5	11.2	7.3
2	Bagram, Afghanistan	AFG_BAG	0.9	16.1	42.1	32.6	5.2	3.1	0.0
3	Khowst, Afghanistan	AFG_SAL	1.8	19.8	47.8	18.6	8.1	3.9	0.0
4	Qatar	QAT_UDE	1.3	14.0	34.7	30.1	15.2	4.7	0.0
5	United Arab Emirates	UAE_DHA	0.8	10.4	28.6	26.2	14.8	16.7	2.4
6	Balad, Iraq	IRQ_ANA	1.9	21.2	50.5	18.6	3.5	4.4	0.0
7	Baghdad, Iraq	IRQ_VIC	0.6	10.3	27.0	28.0	15.9	18.1	0.0
8	Tallil, Iraq	IRQ_ADD	1.9	34.1	44.7	14.8	4.5	0.0	0.0
9	Tikrit, Iraq	IRQ_SPE	1.7	31.8	54.2	11.2	0.0	1.1	0.0
10	Taji, Iraq	IRQ_TAJ	0.6	14.6	56.5	22.3	5.1	1.0	0.0
11	Al Asad, Iraq	IRQ_ALA	2.0	18.6	39.4	22.8	12.4	4.7	0.0
12	Northern Kuwait	KUW_BUE	0.5	11.0	42.0	25.5	10.1	10.8	0.0
13	Central Kuwait	KUW_AAS	1.7	38.8	48.8	9.0	1.6	0.0	0.0
14	Coastal Kuwait	KUW_SHU	1.1	13.9	29.2	21.9	15.3	18.7	0.0
15	Southern Kuwait	KUW_AR1	1.0	17.4	33.6	22.2	16.2	9.7	0.0

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